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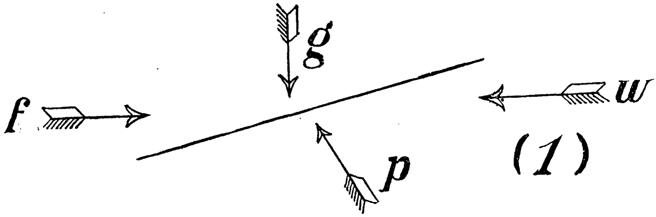
THE FLIGHT OF BIRDS.

By I. Lancaster.

I have been asked what effect the application of soaring methods has upon active wing flight. If soaring goes on so easily where gravity is the motive power, why do not all birds soar?

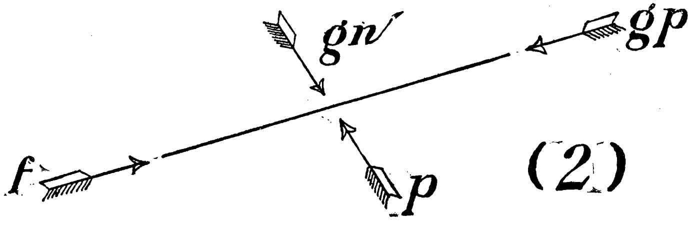
The soaring activity is not understood when such a question is put, obscurity arising, doubtless, from misconception.

The usual statement of soaring held by everybody, and especially by mechanical authority, is diagrammed in 1, where g represents weight, w, horizontal air resistance, and p, normal pressure. When a horizontal force, f, is applied, of sufficient magnitude to cause p to equal both g and w, the plane moves on the horizontal path of soaring flight. Soaring, or indeed any sort of bird flight, would be impossible thus stated, which may be called the formula method.



The soaring statement presented by nature, is seen in 2, where the horizontal force, f, and the horizontal resistance, w, are stricken out. Vertical g is replaced by gn and gp, while p remains the same in direction but not in magnitude. The pressure plane of air throws g out of vertical, making gn and gp out of it; p is equal to gn; f is equal to gp, and the plane soars; f pushes gp *up* as fast as gn pushes p *down*, producing a horizontal resultant.

Compare both statements with 3. In either case a prism of air as wide as the distance across the extended wings of the bird, as thick as the perpendicular distance between the front and rear edges of the wings, and say fifty feet long, is driven out of the way in one second of time. This is done, as above stated, in both cases, but the way of doing it is the vital matter. It is driven out by *gn* and not by *f*. Suppose *f* should stop acting. Motion of bird would then be downward on the normal line, in which motion *gn* would do the same work in one second as before. Motion both ways goes on simultaneously, neither having the slightest effect upon the other, for the reason that they are 90° apart, and rectangular forces do not affect each other, the bird moving under each force as if the other were not acting. The way in which the air is driven out is determined by *f*, but *gn* does all the work. The law of fluid reactions throws all the air resistance to the bird's motion around, normal to the plane of its wings; *gn* then forces it down, while *f* keeps the bird level.



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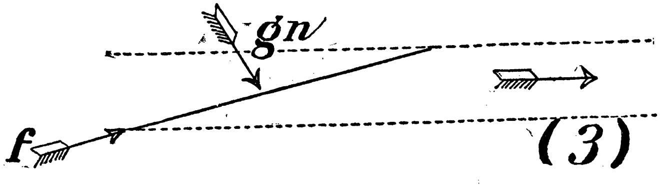


(3)

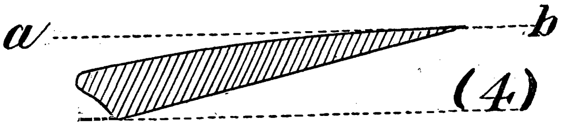
There is yet a very important point to be understood. In methods sanctioned by mechanical authority weight and air resistance are added in pressure. Both are assumed to be resistance to the soaring force. They should be subtracted, not added. *p* is a reaction against *gn* and not a force equal to *gn*, acting with it against the soaring force. Atmosphere resistance to the bird must be overcome, but weight overcomes it, and is itself used up in the exertion.

I once saw a parody on Jack, the Giant Killer. Jack was set upon simultaneously by two giants, either of which could have demolished him at once. He adroitly set them to fighting each other and then cut off their heads. Nature met with much the same problem. She desired a soaring bird. Two antagonists confronted her, air and weight. She so fashioned a bird as to take advantage of the law of fluid pressure, which set weight upon air resistance, in which contest they were both destroyed. She outdid Hercules in details of destruction. Pressure first cut weight into two unequal parts, then fell upon the greater and transformed it into a stream of escaping air condensation, while the smaller still offered resistance. Then from these condensations, equal to the total normal part, she obtained enough force through wing details to destroy the parallel part, and still have a large surplus. And all this was accomplished by a bird's wing. It seems a pity that such a magnificent piece of work should belong only to fishhawks, carrion crows, and the like.

Further, a single matter must be noticed. By referring to 3, it will be seen that there is a region behind and above the lower surface of the bird, and beneath the front edge, of triangular shape, that is not affected by the air. If the bird had but one motion on the upward slant, any thickness of parts, either of wing or body, would resist. But normal motion confines air collision to the under side, leaving a confused mass of eddies and reacting currents at the upper side. This region of eddies may be filled with solid materials and still not destroy the effect of a mathematical plane devoid of thickness. The front edge must be sharp but the rear edge may be overreached, as in 4, without further resistance. Such shape will move farther in the same time unit normally than a flat shape, while parallel motion is not changed in the slightest degree. The least projection above *a b* increases resistance.

I have called this region the "neutral zone," for want of a better name. The bodies of all birds are almost entirely confined to this zone.

The original question is now in order. Why do not all birds soar? For many reasons, among which are the following:



1. A bird may be of such shape that to throw it over to an inclination that gives a parallel factor small enough to be neutralized by the forward thrust would get part of the animal out of the neutral zone. The gray pelican of the Gulf coasts is a case in point; especially when its gullet is full of fish. It must flap to get thrust for its large parallel factor. If its wings were one foot longer on each side, it could doubtless soar continuously, even if its body did encroach on resisting air to some extent.

2. Weight may be too great for surface. In this case condensations escape too readily to be utilized. A wild turkey, prairie-chicken, or pheasant, are examples.

3. Weight may be too little for surface. Here condensation is too weak to give thrust. A species of sea-gull found on the lower Florida peninsula is a good example. In May and June, when food is scarce, they flap continually. In November and December, when food is plenty, they rarely move a wing. They will put into an empty craw their weight in food.

4. Life habits may prevent suitable feather construction. I presume this reason may apply to many small birds.

In the case of bats, the small factor may be entirely neutralized by flapping, as there seems to be at least no surface provision for utilizing the escaping condensations.

Flying squirrels do not sustain themselves.

But in no case of bird flight that I am acquainted with, can it be said that the normal factor is opposed by flapping. That is cancelled by its own work on air. Flapping goes on for the sole purpose of producing parallel motion by either increasing the energy of the condensations, or by a backward push against the air.

It must be borne in mind that the nearer the bird's wings approach horizontal, the less will be the obstructive gravity factor, but on the other hand, the more contracted will be the neutral zone. The moment this zone is encroached upon, more is lost in resistance of air, than is gained by lessening the small factor.

In experimenting, I never pay the least attention to what I have called the "soaring force," meaning thereby the force required to push the plane to the resultant, after the small factor is neutralized. I have never used scales delicate enough to measure this force. The moment the small factor is out of the way, the plane runs to the front to the limit of its freedom.

There is the narrowest possible margin between active and fixed wing flight. The only group of white pelicans I ever met with, eight in number, moved through the air in alternate flapping and gliding motion. Once only, I found them facing a southwester on fixed wings. They rested in the gale as firmly as if fastened to a rigid support. I had been observing them daily for five months and was rewarded by this very unusual exhibition. I shot one of them and found its gullet and intestines full of fish, and it could only spread one square foot of surface to each five pounds of weight, the greatest contrast of surface to weight I ever found.

The entire subject of bird flight has been persistently misconceived. It must be recast in toto to rescue it from the mass of delusion that involves it, To speak of erroneous details is labor lost. It is *all* erroneous. There is no stress in the entire activity, either in direction or magnitude, where stresses are supposed to be. When it is seen that from eleven-twelfths to seventeen-eighteenths, approximately, of total weight is employed in overcoming total air resistance to the bird's motion, it is easily conceivable that the animal may overcome the remaining resistance without the necessity of estimating the muscular exertion of a creature weighing eight ounces in terms of horse power.